CONDUCTIVE FILAMENT

Definition of Terms

[0001] Filament – a shaped body, usually formed of polymeric material, of relatively small cross section and of indefinite length.

[0002] Yarn – *here*: A product formed of at least one filament (=monofilament) or an assembly of filaments (=multifilament)

[0003] Multi-Component Yarn – A yarn formed of two or more different materials and/or of two or more different yarns.

[0004] Conductivity – *definition of what is considered to be conductive*

Background of the Invention

[0005] It has long been known to produce conductive yarns from thermoplastic polymers which are combined with a conductive material such as carbon. In many instances the carbon is combined with the yarn as a coating. This is not wholly acceptable because carbon or carbon loaded polymeric resin does not adhere well which causes flaking or peeling. Another concern is the mass of carbon required in order to generate an acceptable level of conductivity. Because relatively large percentages of carbon must be combined with the polymer resin to make it conductive, the yarn properties are severely compromised. Historically, the carbon content necessary to provide adequate conductivity is more than 25% by weight. The

technical properties of yarns containing this level of carbon content is severely affected.

[0006] Carbon nanotubes, which have recently been developed, are essentially very fine carbon fibers. This nano size allows the use of a low percentage of carbon in a polymeric composition while providing for the requisite conductive properties.

[0007] It is the primary object of the instant invention to provide a multi-component yarn which is conductive, does not flake, is not brittle and has good physical properties.

[0008] Another object of the invention is a multi-component conductive yarn in which no component includes more than 20% carbon by weight.

[0009] Another object of the invention is a multi-component conductive yarn which contains less than 10% carbon by weight.

[0010] Another object of the invention is a multi-component conductive yarn which includes a plurality of components, at least one of which is a conductive filament.

[0011] Another object of the invention is the provision of a multi-component yarn with a conductive sheath secured to a non-conductive core.

[0012] Another object of the invention is a multi-component conductive yarn in which one component includes carbon nanotubes which form the electrical conductor.

[0013] Another object of the invention is a multi-component conductive yarn in which multiple components include carbon nanotubes which form the electrical conductor.

[0014] Another object of the invention is a multi-component conductive yarn which is physically resilient.

[0015] The invention is intended for use in a variety of applications including, but not limited to, lay belts, conveyor belts, braiding, industrial textiles, filtration, paper machine clothing, IFBC shipping bags, upholstery, home furnishings, hook and loop, carpets, apparel, nonwovens, brushes and process forming belts.

Summary of the Invention

[0016] The invention is directed to a multi-component conductive yarn and the method of forming. The yarn comprises a primary component and a secondary component. The primary component consists of an elongated filament formed from polymeric material. The secondary component consists of a fiber of a polymeric material and carbon nanotubes which is bonded with the primary component along its length. The carbon included in the secondary component includes up to 20% by mass of carbon nanotubes. The secondary component when combined with the first component provides a conductive yarn which comprises no more than 10% carbon nanotubes by weight.

[0017] The polymeric material forming the primary component may be one of any melt-spinnable polymer, preferred is one of or a blend of polyester (such as PET, PTT, PBT, PCTA, Polycarbonate, etc.), polyamide, PPS, polypropylene, polyethylene and/or PEEK. The polymeric material of said secondary component includes at least 80% of one of polyester, polyamide, PTT, PBT, PPS, polypropylene, polyethylene and

PEEK while carbon nanotubes comprise the remainder of the makings of the component.

[0018] The secondary component may comprise a sheath surrounding the filament of the primary component. Alternatively, the secondary component may comprise an elongated filament bonded with the filament of the primary component along its length.

[0019] The secondary component may wrap around the primary component as it extends along its length.

[0020] The secondary component may comprise between 0.5% and 50% by weight of the multi-component yarn while the carbon nanotubes may comprise up to 20% by weight, preferred no more than 15% by weight, of the secondary component.

[0021] The primary component may be a yarn which has been stretched and heat set prior to being combined with the secondary component. Alternatively, the first and second components may be extruded simultaneously and joined forming the multi-component yarn. The so formed yarn may then be stretched and heat set. Such a yarn is called a heterofilament yarn.

[0022] The invention further includes a method of forming a conductive multi-component yarn. The method includes the steps of providing at least a first component consisting of at least one elongated filament of polymeric material. Also, providing at least a second component consisting of a composition including a polymeric resin and carbon nanotubes. Limiting the carbon nanotubes to between 0.5% to 20% of the composition of the second component. Passing the first

component through a crosshead extruder in the form of a filament while the second component is extruded onto the first component causing it to bond therewith forming the composite yarn as a core filament comprised of the first component with a conductive sheath formed there about. This type of yarn is called a coated yarn. Alternately, the method may comprise simultaneously extruding the first and second components forming multiple filaments and causing the filaments to bond together along their length. This type of yarn is called bonded filaments.

Description of the Drawings

[0023] The construction designed to carry out the invention will hereinafter be described, together with other features thereof.

[0024] The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings forming a part thereof, wherein an example of the invention is shown and wherein:

[0025] Figure 1 is a schematic view showing a process forming a multi-component yarn of the invention. It is the coating process of the first component with a second component by a crosshead extruder.

[0026] Figure 2 is a schematic view showing another process for forming a multi-component yarn of the invention.

[0027] Figure 3A is a cross sectional view of a multi-component yarn of the invention.

[0028] Figure 3B is a cross sectional view of another multi-component yarn of the invention.

[0029] Figure 3C is a cross sectional view of another multi-component yarn of the invention.

[0030] Figure 3D is a cross sectional view of another multi-component yarn of the invention.

[0031] Figure 3E is a cross-sectional view of another multi-component yarn of the invention.

[0032] Figure 3F is a cross-sectional view of another multi-component yarn of the invention.

[0033] Figure 3G is a cross-sectional view of another multi-component yarn of the invention.

[0034] Figure 4 is a diagrammatic view showing aligned nanotubes.

Description of a Preferred Embodiment

[0035] Referring now in more detail to the drawings, the invention will now be described in more detail.

[0036] Carbon nanotubes are extremely small conductive elements which have found use with polymers as a conductive additive. A primary advantage of carbon nanotubes is that they possess a higher aspect ratio than carbon black particles or chopped carbon which allows for a lower additive loading while maintaining adequate levels of conductivity.

[0037] Carbon nanotubes comprise elongated particles which tend to intertwine and have a low sensitivity to shear fields. This provides the capability of elongating the polymeric resin containing carbon nanotubes without entirely severing the carbon nanotube agglomerates which are formed within the polymer. Figure 4 schematically shows generally the manner in which carbon nanotubes can be distributed in a polymeric resin.

[0038] In a conductive yarn it has been most difficult to produce a yarn which retains most of the desired fiber characteristics normally achieved from the original polymer resin due to the negative impact of the carbon. A major contributor to this problem is the amount of carbon necessary to provide for the fiber to be sufficiently conductive. If the carbon additive is combined with the polymer in the form of a coating, the coating has the tendency to peel and crack.

[0039] The instant invention provides to overcome these drawbacks by providing a conductive multi-component yarn which retains the desired physical characteristics, is flexible and does not peel or crack.

[0040] Turning now to Fig 1, a supply 10 comprising a set filament 12 is seen being passed through at least one but preferably a plurality of extruder dies which extrude a coating or adhering resin compound 14 onto the filament 12 as it passes. Resin compound 14, in this instance, forms a sheath 16 about filament 12. Also, in this instance, as filament 12 is already stretched and heat set, sheath 16 is allowed to solidify and the multi-component yarn 18 is simply rewound for shipment.

Alternatively, the multi-component yarn could be passed between draw rolls and through an oven where the yarn is stretched, relaxed, or both and then heat set.

[0041] The multi-component yarn 18 may comprise a core usually formed of a polyester (such as PET, PTT, PBT, PCTA, etc) or a polyamide fiber. The core could alternatively be polypropylene, polyethylene, PPS, PEEK or other melt-spinnable polymers or a blend of these polymers. The core may comprise one or a plurality of filaments. It can also be a yarn made of natural fibers and staple fibers.

[0042] The sheath comprises a polymer, again usually a polyester or a polyamide combined with carbon nanotubes. Again, the above listed resins could also comprise the polymer forming the sheath.

[0043] Resin compound14 comprises between 0.5% to 20% carbon nanotubes and between 80% to 99.5% polyester or other polymer or blend of polymers. Sheath 16 comprises between 0.5% to 50% of the mass of the multi-component yarn while core 12 forms between 50% to 99.5% of the multi-component yarn.

[0044] The nanotubes within resin 14 are interspersed along the length of the sheath and about the core providing a conductive artery along the length of the multi-component yarn. The percentage of the multi-component yarn consisting of carbon nanotubes is between 0.5% and 15%. Such a low percentage of carbon allows the resins forming the compound 14 to maintain substantially all of their normal features such as elasticity, strength and elongation. Normally the core of the multi-component yarn retains all of its usual characteristics as it is formed of 100% polymer.

[0045] In a second arrangement for forming the multi-component yarn, yarn 12 is pre-formed but not set. Yarn 12 is drawn from supply 10 and passes through the extruders extruding compound 14 producing yarn 18 as earlier described. In the alternative arrangement, the just formed multi-component yarn is passed between draw rolls and through an oven where the yarn is stretched, relaxed, or both and then heat set. Both the core 12 and sheath 16 are treated and then set. This is possible due to the innate characteristics of carbon nanotubes which are not so easily separated but remain substantially in contact and because of the limited percentage of nanotubes present in the sheath 16.

[0046] Other arrangements are shown in Fig 2. In a first arrangement a pair of extruders 20, 22 are shown. Extruder 20 extrudes the core yarn 12 while extruder 22 extrudes the second component 24. The extruders are controlled in known manner which allows the second component 24 to adhere to core 12 along its length in the form of an elongated filament 28. Figure 2 also represents the heterofilament process. In this case both components are molten in their extruders 20 and 22 and pressed into a special designed spinhead in which both components are simultaneously spun into a multi-component yarn 28.

[0047] The multi-component yarn 28 shown in Fig 3 is passed between draw rolls 30, stretched and/or relaxed and then heat set by heater 32.

[0048] It is noted that component 24 may be dispensed in the form of sheath 16 as shown in Fig 3A which encases the core along its length. The extruded compound 24 can be controlled to attach to the core 12 in the form of a wedge shaped filament

26 or an additional filament 26 which extends along the length and is wrapped about its axis of core 12 as shown in Figs 3B and 3E. Another arrangement could be for core 12 to be arranged on opposed sides of compound 24 which assumes the form of a conductive strip 26' which extends along the length of core 12 as shown in Fig 3C. The extruded compound 24 could form a plurality of wedge shaped filaments 26 or additional filaments 26 which are arranged along the length of core 12 as shown in Figs 3D and 3F. Another arrangement could be for core 12 to be first coated by sheath 36 and then by conductive sheath 16. Sheath 36, which is preferably a low melt polymer, adhesive type polymer, co-polyester or other suitable material, provides an intermediate layer which provides increased adhesion between the core 12 and the conductive sheath 16. In each of the arrangements sheath 16, filaments 26 and strips 26' form a conductive filament which is adhered with core 12 along its length.

[0049] In all arrangements, the percentage of the first component or core polymer and the percentage of the second component or conductive polymer + carbon nanotubes remains within the set forth limits.

[0050] It is noted that the core could consist of a plurality of filaments which are preferably but not necessarily of the same polymer. The core could consist of a blend of polymers. Also the sheath or conductive filament could consist of a blend of polymers combined with the carbon nanotubes.

[0051] The multi-component conductive yarn of the invention is intended for use with a multiple of fabric types such as woven fabrics, knitted fabrics, braided fabrics, non-woven fabrics, interlaid fabrics and composite fabrics. The yarn is

intended to comprise varying selected percents of yarns forming these fabrics. Also, the yarn is intended for use with any combination of the above fabric types.

[0052] While a preferred embodiment of the invention has been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.